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Effects of Biomass Feedstock on the Yield and Reactivity of Soot from Fast Pyrolysis at High Temperatures

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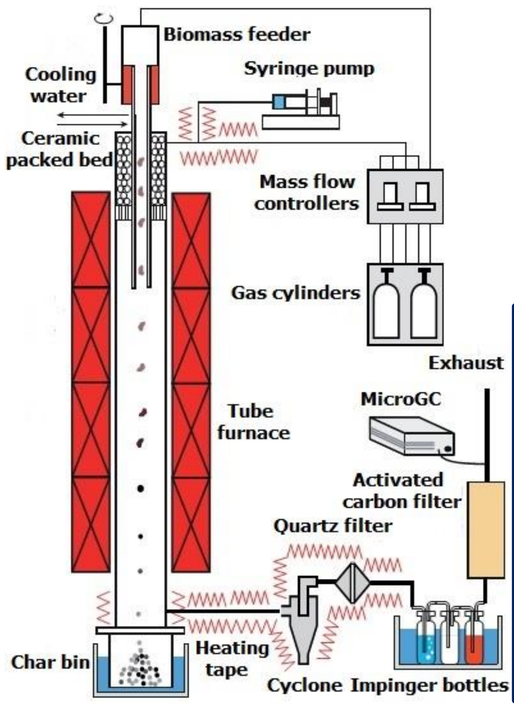
ABSTRACT - This study investigated the effect of feedstock on the yield, nanostructure and reactivity of soot. Woody and herbaceous biomass were pyrolyzed at high heating rates and temperatures of 1250 and 1400°C in a drop tube furnace. The collected solid residues were structurally characterized by electron microscopy techniques, X-ray diffraction and N_2-adsorption. The reactivity of soot was investigated by thermogravimetric analysis. The results showed that the reactivity of soot, generated at 1400°C was higher than that at 1250°C for all biomass types. Wood and wheat straw soot demonstrated differences with respect to the alkali content, particle size and nanostructure. Potassium was incorporated in the soot matrix and to a significant extent influenced the soot reactivity. The particle size distribution of pinewood soot produced at 1250°C was in the range from 27.2 to 263 nm which was broader compared to that of beechwood soot (from 33.2 to 102 nm) and wheat straw soot (from 11.5 to 165.3 nm). In addition, pinewood soot particles contained mainly multi-core structures at 1250°C. The potassium content played a more important role on the soot reactivity than the particle size and nanostructure.

Biomass Feedstock Composition

	Pinewood	Beechwood	Wheat straw	Alfalfa straw	Leached wheat straw
Moisture (wt.%, ar)	5.1	4.5	5.5	5.2	4.3
Ash (at 550°C) (wt.%, db)	**0.2**	**1.4**	**4.1**	**7.4**	**2**
Cellulose (wt.%, db)	38.3	35	35.9	18.8	32.1
Hemicellulose (wt.%, db)	17.8	19.2	18	12	23.5
Lignin acid insoluble (wt.%, db)	29.6	32	**19.2**	14.7	**13.8**
Lignin acid soluble (wt.%, db)	1.8	1.5	**6.5**	6.8	**2**
Extractives (wt.%, db)	8.8	7.5	10.1	39.6	13.3
Protein (wt.%, db)	0.6	1.9	6.3	5.1	1.3
K (mg kg^{-1}, db)	200	3600	**11000**	28000	**1300**
Ca (mg kg^{-1}, db)	600	2000	2500	12900	1300
Si (mg kg^{-1}, db)	50	200	8500	2000	6200

Methodology

Drop tube reactor



Soot
Collected at 1250-1400 °C

1 → **Yields & Composition**
- Organic
- Ash

2 → **Soot characterization**
- TEM microscopy (particle size, and shape, nanostructure)
- TEM EELS analysis
- Ash compositional analysis
- FTIR analysis
- X-ray diffraction

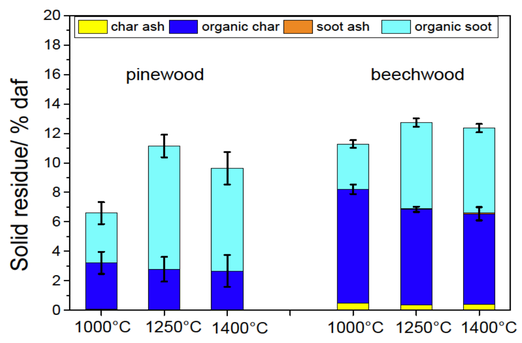
3 → **Reactivity ($10°C\ min^{-1}$)**

5 vol.% O_2 + 95 vol.% N_2
5 vol.% CO_2 + 95 vol.% N_2

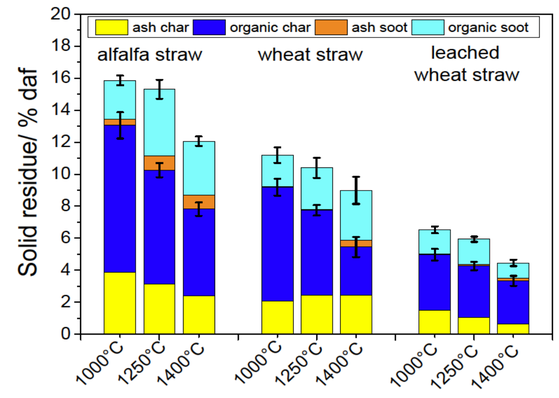
(TGA measurements were conducted dynamically)

Soot yields

Pinewood and beechwood



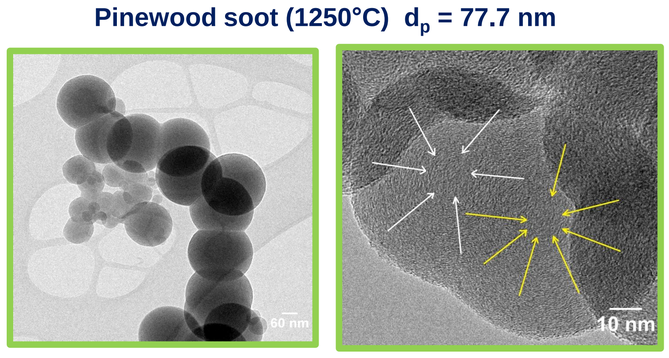
Wheat straw, alfalfa straw and leached wheat straw



- The ash content of soot increased with the higher temperatures
- Soot yield from wood is higher than that from straw samples (high K, low lignin)
- Soot yield decreased by leaching wheat straw (leached wheat straw has lower lignin and K)
- Lignin has a stronger influence on the soot formation than potassium

TEM investigations

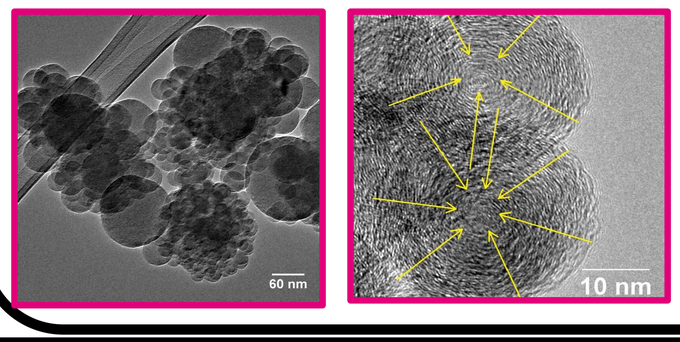
Pinewood soot (1250°C) d_p = 77.7 nm



1. Pinewood soot:

- Mainly multi cores soot particle
- Distance between cores is large
- More amorphous structure

Wheat straw soot (1400°C) d_p = 30.8 nm

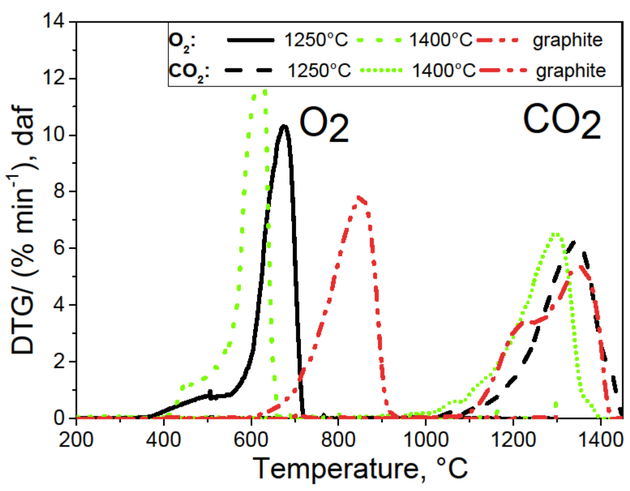


2. Wheat straw soot:

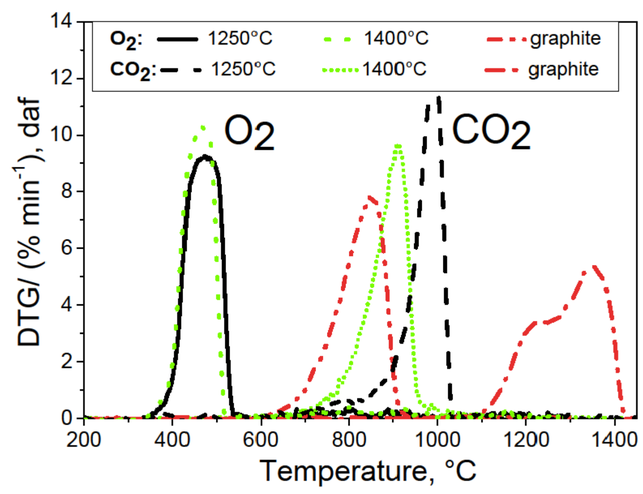
- Mainly single core particles
- More graphitic structure

Reactivity

Pinewood soot



Wheat straw soot



- Pinewood and wheat straw soot samples prepared at 1400°C were more reactive in CO_2 gasification than soot prepared at 1250°C
- Pinewood was less reactive wheat straw soot towards O_2 and CO_2

Conclusion

- The thermogravimetric analysis results showed that the reactivity towards O_2 and CO_2 of soot depends mainly on the potassium content in the original fuel and on the heat treatment temperature and less on the soot nanostructure
- Soot yields from pyrolysis of pinewood and beechwood were higher than from wheat straw and alfalfa straw
- Low lignin content leads to the lower soot yields and has stronger influence on soot yields than potassium

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